PRODUCT AND PROCESS INNOVATION IN MANUFACTURING FIRMS—A THIRTY-YEAR BIBLIOMETRIC ANALYSIS.

Authors:

Giacomo Marzi
Lincoln International Business School
gmarzi@lincoln.ac.uk

Marina Dabić
University of Zagreb Faculty of Economics and Business,
Nottingham Trent University,

Tugrul Daim
Portland State University, US

Edwin Garces
Portland State University, US

PRODUCT AND PROCESS INNOVATION IN MANUFACTURING FIRMS—A THIRTY YEARS BIBLIOMETRIC ANALYSIS.

Abstract - *Built upon a thirty-year dataset collected from the Web of Science database, the present research aims to offer a comprehensive overview of papers, authors, streams of research, and the most influential journals that discuss product and process innovation in the manufacturing environment. The dataset is composed of 418 papers from more than 150 journals from the period between 1985 and 2015. Homogeneity analysis by means of alternating least squares (HOMALS) and Social Network Analysis (SNA) are used to accomplish the objectives listed above through the keywords given by authors. Initially, the paper highlights and discusses the similarity between the topics debated by the main journals in this field. Subsequently, a wide-range map of topics is presented highlighting five main areas of interests; namely, performance, patent, small firm, product development, and organization. A SNA is also performed in order to validate the results that emerged from HOMALS. Finally, several insights about future research avenues in the manufacturing field are provided.*

Keywords: product, process, innovation, manufacturing, field, bibliometric, scientometrics, keywords, literature, review, future, HOMALS, social network analysis, SNA

Mathematics Subject Classification: 91-02

JEL Classification: M11

1. Introduction

Innovation in manufacturing is a traditional field of study (Schroeder et al., 1989; Terziovski, 2010; Aas et al., 2015), and several studies have assessed the relationship between the prosperity of a firm and the ability to sustain a continuous innovation process (e.g. Adner and Levinthal, 2001). Management scholars have repeatedly remarked about how innovativeness is a critical factor for manufacturing firms' survival and growth (Damanpour, 1991; Smith and Tushman, 2005; Knight and Cavusgil, 2004; Buffington, 2016; Visnjic et al., 2016). Moreover, in the manufacturing field, the innovation process it is mainly realized by the introduction of innovative products and processes (e.g. Becheikh et al., 2006) that promote the ability of organizations to enter or create new markets to satisfy the demand of customers and to be competitive (Smith et al., 2005). However, in recent decades, challenges in the competitive arena of manufacturing have grown exponentially. Nowadays, companies are experiencing extreme competition due to increasing pressures from technological changes and global challenges (Shepherd and Ahmed, 2000; Davies, 2004; Caputo et al., 2016).

Consequently, the body of literature around the concept of product and process innovation in manufacturing firms has dramatically changed (Reichstein and Salter, 2006; Antonioli et al., 2014; Wu et al., 2015) producing a large amount of papers covering this multifaced and vast phenomenon. However, inside the body of knowledge on product and process innovation in manufacturing firms there is not a recent snapshot that offers a comprehensive perspective regarding the main topics studied, the evolution of this field, the main findings, and the possible direction of future research.

To address such a gap, we propose a bibliometric study that covers the years from 1985 to 2015. In fact, bibliometric studies have shown their usefulness in a broad range of fields such as management (Podsakoff et al., 2008), entrepreneurship (Landström et al., 2012; Marzi et al., 2017a; 2017b), expatriates (Dabic et al., 2015), corporate social responsibilities (Dabic et al., 2015), supply chain (Gonzalez-Loureiro, et al., 2015), operations management (Hsieh &

Chang, 2009; Zhu et al., 2015), and innovation (Fagerberg et al., 2012; Appio et al., 2016) by helping scholars to sort the streams of research from the "tangled forest" of the scientific proliferation. Thus, the data collected in this paper covers thirty years of research in such a field (1985-2015) allowing scholars to have a wider picture of the knowledge base created. Indeed, the pertinent literature seems to lack a comprehensive and recent analysis of the evolutions in this area of research. Moreover, the last valuable literature analysis is from Becheikh et al., (2006) which includes researches from 1993 till 2003. Thus, an update and a comprehensive snapshot is needed.

Likewise, the paper aims to help innovation scholars to better understand the direction in which the field is going and where the gaps are to provide a guideline for scholars in positioning their future research focusing on two questions. First, who has published the most literature about product and process innovation in manufacturing and where was it published, and what was their contribution to the evolution of the field? Second, what is the content and the association between topics in innovation manufacturing literature?

Following Brown and Eisenhardt (1995) and Furrer et al., (2008) the first question encompasses the identification of the most productive authors in the field, the identification of key results in the most relevant papers, and the presentation of the journals and their impact in the field under study (namely paragraph 3 and 4.1). To address the second point, we use the keywords given by authors to identify the main topics that were studied resulting in a representation of the various subfields in product and process innovation in manufacturing (specifically paragraph 4.2 and 5). In particular, with the keyword analysis, we want to define how the sub-topics (viz. the keywords) are naturally grouped together in research streams and how these particular sub-topics are naturally evolving into a complex system of interconnected sub-topics.

In addition, unlike the respected study of Becheikh et al., (2006), our analysis of the structure of the product and process innovation field is based on quantitative data rather than qualitative interpretation, which may reflect the subjective views of their authors (Furrer et al., 2008). Both types of studies are valuable and complementary, hence our results may also be used to validate previous interpretations.

Consequently, using an HOMALS and Social Network Analysis (SNA) we aim to address such a gap and to provide a broader look at what has happened over the last thirty years (1985-2015) in terms of collected research. We chose to use HOMALS for its ability to show in a simple way the primary areas of interest in a large set of data (Furrer et al., 2008; Gonzlalez-Louriero et al., 2015). In this research, SNA is used as a support tool to highlight the connection between journals and keywords that are not possible to develop only with HOMALS (Otte and Rousseau, 2002).

Hence, the paper is structured as follows: after the introduction, section two presents a review of literature on innovation, especially in the manufacturing field. Section three describes data gathering, methodological notes about HOMALS and SNA analysis, and an analytical description of the sample. Section four shows the results of HOMALS by first presenting the journals, and then the keywords mapping allowing an evaluation of disciplinary trends. Section five presents the results coming from the SNA, and finally, the last section is reserved for a discussion about the future of product and process innovation in the manufacturing field, and provides extensive insights into the probable future development of the field.

2. Literature Review

Centuries ago, Adam Smith in his cornerstone essay "Wealth of Nations" (1776) emphasized that innovation demands the investment of capital, but is a crucial economic activity to fostering wealth. However, even if the importance of innovation was recognized in the18th century, a formal explanation of innovation was provided only by Schumpeter (1934) two centuries after. He focused on the role of economic factors in technical advancement, and underscored that innovation is a necessary and essential driver of economic development. Moreover, Schumpeter offered a distinction between the inventor and the entrepreneur. An entrepreneur is an actor who recognizes an unsatisfied need and creates a product to fulfill this need, whereas a manager simply organizes the work. Furthermore, according to Schumpeter, economic development is a "creative destruction", characterized by established monopolies that are only temporary as a result of the "catching up" of newcomers. In the ideal market environment, where competition thrives, imitation would significantly affect profits, reducing it to normal levels. Consequently, Schumpeter's (1942) conclusion is that it is impossible to achieve perfect competition alongside entrepreneurship. Schumpeter referenced the innovation process, but was unsuccessful in providing an explanation that specifically pertains to how innovations come about.

In this vein, Arrow (1962) presented a counter explanation that focused on an investigation into how resources are allocated for innovation processes. With competition not isolated to a single industry, but rather emerging from any industry, innovative competition produces higher levels of uncertainty and several resources need to be allocated to the innovation process to compete in a rapidly changing environment.

Thus, Schumpeter's original theory has been the basis of subsequent empirical economic literature, which has drawn on the concept of innovation as a driver of economic growth. An extensive body of empirical evidence currently exists across countries pertaining to innovation (Lichtenberg, 1993; Coe and Helpman, 1995; Engelbrecht, 1997; Guellec and de la Potterie, 2001), and is now an issue companies must confront if they desire to develop and maintain a competitive advantage and/or gain entry into new markets (Brown and Eisenhardt, 1995; OEDC, 1997; Webb, 2007). It is also indicative of one of the key factors that impact countries' international competitiveness, productivity, output, and employment performance (Asheim and Isaksen, 1997).

Though, Schumpeter evidently presented his definition of innovation within the context of the firm and delineates its extent as product, process, and business model, the debate is ongoing regarding various aspects of invention, including its necessity and sufficiency (Pittaway et al., 2004), intentionality (Lansisalmi et al., 2006), beneficial nature (Camison-Zornoza et al., 2004), successful implementation (Hobday, 2005), and its diffusion (Peres et al., 2010), all of which could provide a more qualifying definition of innovation. As such, OECD (1997) offered this definition of innovation that encompasses all the scientific, technological, organizational, financial, and commercial activities essential to the creation, implementation, and marketing of new or improved products or processes.

However, innovation is a widely multifaceted phenomenon and the aforementioned definition does not cover all of the possible layers of this circumstance. Consequently, Crossman and Apaydin (2010) developed a more comprehensive definition of innovation that is the "production or adoption, assimilation, and exploitation of a value-added novelty in economic and social spheres; renewal and enlargement of products, services, and markets; development of new methods of production; and establishment of new management systems" (p. 1155).

Hence, this definition catches several vital facets of innovation: it includes internally conceived and externally adopted innovation; it stresses innovation as more than a creative process; it underlines intended benefits; it leaves open the possibility that innovation may refer to relative newness of an innovation; and finally, it draws a focus to the two roles of innovation, namely a process and an outcome.

Management scholars dedicated a specific attention to innovation and several studies have assessed the relation with the prosperity of a firm to the ability to sustain a continuous innovation process (e.g. Adner and Levinthal, 2001). Innovation in manufacturing is a traditional field of study (Schroeder et al., 1989; Terziovski, 2010; Aas et al., 2015), and management literature has conventionally considered innovation as one of the major factors of long-term performance in present-day environments (Clark & Fujimoto, 1991; Drucker, 1994;

Kanter, 2001). Moreover, management scholars have repeatedly remarked about how innovativeness is a crucial factor for manufacturing firms' survival and growth (Damanpour, 1991; Smith and Tushman, 2005; Knight and Cavusgil, 2004; Buffington, 2016; Visnjic et al., 2016).

Accordingly, the management literature on innovation emphasizes the classification between administrative innovation and technical developments concerning the organizational process (Daft, 1978; Kimberly and Evanisco, 1981; Damanpour, 1987; the dichotomy between product innovation and process innovation of innovation (Utterback and Abernathy, 1975); and the distinction between incremental innovation and radical innovation as pertaining to the level of technological advancement imprinted within the organization (Ettlie et al., 1984; Dewar and Dutton, 1986; North and Tucker, 1987).

In the last decades, management scholars analyzed a vast area of topics connected to innovation in the manufacturing field. For example, Veugelers and Cassiman (1999) analyzed innovation strategies in manufacturing firms, and found that high perceived risks and costs and low appropriation of innovations does not discourage innovation, but rather determines how the innovation sourcing strategy is chosen. The authors found that small firms are more likely to restrict their innovation strategy to an exclusive make or buy strategy, while large firms are more likely to combine both internal and external knowledge acquisition in their innovation strategy.

Directly connected to the innovation strategies, Amara and Landry (2005) examined the role of sources of information on the novelty of innovation in manufacturing firms taking in consideration four categories of sources of information that firms use to develop or improve their products or manufacturing processes: internal sources, market sources, research sources, and generally available sources of information. The authors discovered that manufacturing firms use a large variety of sources of information, and that the manufacturing firms prefer to use a large variety of research sources to develop or improve their products or processes. Thus, the novelty of innovation could be increased in developing policies encouraging stronger linkages between firms and government laboratories and universities.

Once more, management scholars have given extensive attention to how product and process innovation plays a fundamental role in this field of study. Becheikh et al., (2006) clearly highlights product innovation as the most studied topic in the field with 37% of papers focused on this topic, and 43% of papers taking into consideration process innovation together with the product. It is interesting to observe that only 1% of papers take into account only process innovation. This shows that these two types of innovation are strictly connected to the manufacturing environment even if product innovation receives more attention from scholars and managers.

More focused on innovation for competition, Nieto and Santamaria (2007) investigated the critical success factors behind more novel product innovations. The authors stressed the role of diverse types of collaborative networks in reaching product innovations and their degree of novelty. They proved that a strong collaboration between suppliers, clients, and research organizations have a positive impact on the novelty of innovation, while collaboration with competitors has a negative impact.

On the organization side of innovation in manufacturing firms, Alegre and Chiva (2008) studied how organizational learning capability affects product innovation performance. Using a five-dimensional model (experimentation, risk taking, interaction with the external environment, dialogue, and participative decision making), the authors stressed the importance of learning in innovation performance, especially for manufacturing firms.

On the side of green production, Lin et al. (2013), highlighted the increasing importance given to market demand of green products pushing manufacturing firms to enhance their efforts to address this new market. The authors also stressed if and how green product innovation can

affect firm performance. Thus, the paper shows that market demand is positively correlated to both green product innovation and firm performance. Surprisingly the demand of green product leads manufacturing firms to a better performance by the pushing for a continuous innovation process.
More recently, as a particularly new and interesting field of studies, De Massis et al. (2015), analyzed how manufacturing family firms managed product innovation. Using a resource-based view approach reinforced by agency, stewardship, and behavioral theories, the authors showed that family businesses contrast from nonfamily firms in product innovation strategies and organization of the innovation process. Thus, manufacturing family firms focus their efforts on incremental product innovations, while nonfamily firms are more focused on breakthrough and radical innovation. Furthermore, family firms use more external sources of knowledge and technologies during innovation activities, while nonfamily firms predominantly adopt a closed approach. Finally, family firms are more risk-averse in their decisions about product innovation, while nonfamily enterprises tend to embrace major risk taking.
Still, in the last years the manufacturing environment has continually and dramatically evolved, undergoing to extensive changes (Castellacci, 2008; Buffington, 2016). The advent of Internet-based technologies has led to the emergence of new manufacturing philosophies such as remote manufacturing, computer-integrated manufacturing systems, and Internet-based manufacturing (Bi et al., 2008; Caputo et al., 2016, Holmstrom et al., 2016). These innovative approaches completely redefine the concept of manufacturing and innovation in the manufacturing field creating totally new avenues of research (Roos, 2015).
The most famous one is Industry 4.0, which using Cyber-Physical Systems to monitor and synchronize physical factory and cyber computational space (Lee et al., 2015). Using advanced information analytics, networked machines, and big data, this up-and-coming revolution will be able to achieve more efficiency and more control and collaboration over the manufacturing environment transforming the manufacturing industry into Industry 4.0.
Accordingly, with this brief literature review, we showed that the stream of research inside product and process innovation in manufacturing firms undergone through numerous changes in these years, especially the last five years. In fact, especially the concept of Industry 4.0 will certainly be a trending topic in the next year both for academic and practitioner. In this vein, taking a snapshot of the current situation represents a vital step to build up the future of this field. Thus, we discuss this new trend in the conclusion part of our paper, and give several scholarly insights about the possible evolution of manufacturing industry.

3. Method

The first step of the research process concerns the sample selection. In doing so, we have selected the Thomson Reuters Web of Science™ database. Inside the database, we have selected the Web of Science Core Collection because it offers the most valuable and high-impact collection of papers (Falagas et al., 2008). In particular, the journals included in Web of Science Core Collection have met the highest standards regarding impact factor and number of citations.
The research query to gather the data was done on January 25th, 2016 with the following research terms limited to the English language, “Article” as the document type, and the time span as 1985-2015:

TS=("product innovation" OR "process innovation") AND TS=(manufactur)*

Where “TS” means “Topic” on the Advanced Research page. We received 566 results in all research areas, we refined the sample by applying “Business and Economics” as a research area, and finally, we received a dataset of 418 papers.

The indexes covered by the data gathering are the following: Science Citation Index Expanded, Social Sciences Citation Index, and Arts & Humanities Citation Index. These indexes contain journals that rank competitively among the most highly-cited core journals in their category or categories covering only the most highly cited, highest impact journals in each category (Leydesdorff et al., 2013).
Moreover, in order to ensure the inclusion of all relevant data, a cross-validation was made with Scopus and Google Scholar using the same research terms applied to Thomson Reuters Web of Science™. Finally, a manual screening was operated to ensure the reliability of data collected.
Regarding the following paragraph, we used Rapid Miner Studio 7.3 to operationalize the data in paragraph 3.3 (Hofmann and Klinkenberg, 2013), R 3.25 Statistical Package to perform HOMALS analysis (De Leeuw and Mair, 2009), and UCINET 6.0 for SNA (Borgatti et al., 2002; Zahao and Chen, 2014; Zhang et al., 2015).

3.1 Methodological notes about HOMALS analysis

In order to achieve the objective mapping of research streams by an extensive number of papers, this approach is using qualitative data and quantitative background derived from multiple correspondence analyses (Hoffman and De Leeuw, 1992; Furrer et al., 2008; Dabic et al., 2014). HOMALS procedure (homogeneity analysis by means of altering at least one square) estimates category quantifiers in two-dimensional space by demonstrating keyword association based on the frequency of joint appearances (Gifi, 1990). Further analysis for mapping the specific research area is based on author keywords that appeared in at least two papers. The usage of keywords is accepted by the literature and successfully applied also to other research areas (Su and Lee, 2010; Yoon et al., 2010; Chang et al., 2015; Khan and Wood, 2015). After this, each selected paper is given a binary value (0, 1) for each descriptor. Zero values are given to papers whose title and abstract didn't contain specific keywords and vice versa. Then we create a data matrix with papers as cases and keywords as binary variables.
The main outcome of this procedure is a proximity map where keywords are represented along two axes. The points on the map represent the distance between keywords. On the resulting plot, the closeness between keywords matches their shared-substance: keywords are adjacent each other due to a substantial proportion of articles that treat them together. On the opposite side, they are distant from each other when a trivial portion of paper has these keywords together (Furrer et al., 2008). The outcome is demonstrated by proximity plot showing homogeneous subgroups of words associated with the number of joint appearances (Bendixen and Sandler, 1995).
The distance is computed from the coordinates of each keyword generated by the HOMALS. The distance between the *a*th keyword with coordinates (x*a*, y*a*) and a second one *b*th with coordinates (x*b*, y*b*) is computed by the following equation:

$$d_{ab} = \sqrt{(x_b - x_a)^2 - (y_b - y_a)^2}$$

Where d_{ab} is the distance from *a* to *b*. Thus, the larger the distance the lesser the association between the keywords. Finally, both axes are then divided into two segments by calculating the respective medians.

3.2 Methodological notes about SNA analysis

SNA is not a formal theory, but a wide-ranging strategy for exploring social structures. In SNA, the relations between the actors are the first objective and relational information is the focus of the investigations (Wellman and Berkowitz, 1998). Regarding SNA, several concepts of the

methodology need to be known in order to fully understand the output of the research. We are limiting our explanation only to what is needed for this paper; in particular, density is an indicator of the level of connectedness of a network. It is given as the number of lines in a chart divided by the maximum number of shapes. Degree centrality is equivalent to the number of connections that a node has with other items in the network. In the following network that we will present, a central item (in this case a keyword) means that it is connected (in the sense of co-appearances) with many other keywords. The more a keyword has a degree of centrality, more it is influencing other keywords. Moreover, betweenness is based on the number of shortest paths passing through an item (a keyword). Keywords with a high betweenness play the role of connecting different groups as bridges (Otte and Rousseau, 2002).
Thus, we cansay that SNA is a viable tool for our purpose of mapping the connection between the keywords and the journal, and as a support tool to make a comparison with the HOMALS technique (Al et al., 2002).

3.3 Sample description and analysis

The data collected shows the following distribution (Figure 1) over the past thirty or so years. Even though the time span was set to 1985-2015, the first paper connected to this query didn't appear until 1988. However, we determined that the academic interest in this field started in 1992 where we found five papers. After this period, the academic interest in this field slowly grew until 2008. In fact, from Figure 1 is possible to see that this area of research had a robust growth from 2008 to 2015 with an average of 35.12 papers per year and an average growth rate of 20.55% in this period. The tendency line is made by a mobile average over three years.

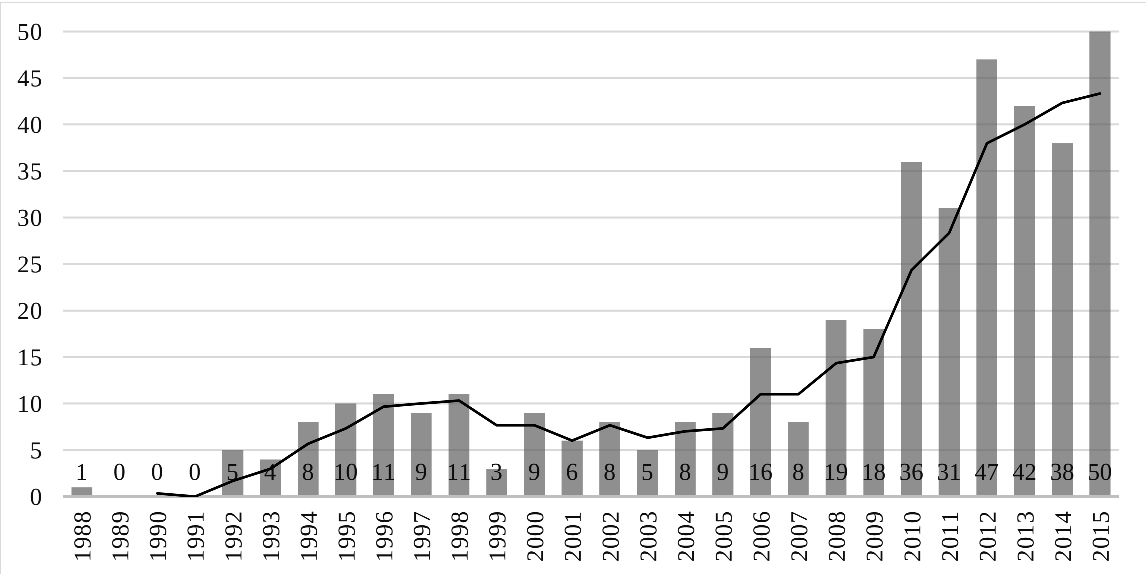

Figure 1: Papers distribution from 1988 to 2015

There is a huge debate around how to measure the impact of journals and papers (Amin and Mabe, 2004; Garfield, 2006; Hall and Page, 2015), however, three useful measures are well accepted by the literature regarding the journals and papers. They are the total number of papers, the total number of citations, and the average citation per paper (Duy and Vaughan, 2006; Garfield, 2006; Garfield and Pudovnik, 2015).
Thus, the following table (Table 1) shows the papers' distribution among the journals. In this representation, the journals are ordered by the total number of citations, with only journals that have more than 100 total citations included (Duy and Vaughan, 2006). By analyzing the table, it is possible to recognize a difference in a journal's main topic. Thus, it is possible to find a

high percentage of journals related to management, technology management, and economics instead of engineering.

N.	Journal	Total Number of Citation	Total Papers	Average Citations per Paper
1	*Journal of Product Innovation Management*	969	31	31,26
2	*Research Policy*	756	24	31,50
3	*Management Science*	534	5	106,80
4	*Technovation*	474	20	23,70
5	*Small Business Economics*	365	10	36,50
6	*Journal of Business Research*	362	10	36,20
7	*International Journal of Operations & Production Management*	325	14	23,21
8	*Journal of Operations Management*	299	7	42,71
9	*Organization Studies*	271	2	135,50
10	*Harvard Business Review*	262	2	131,00
11	*Industrial and Corporate Change*	255	13	19,62
12	*Journal of the Academy of Marketing Science*	249	2	124,50
13	*Academy of Management Journal*	230	2	115,00
14	*Decision Sciences*	181	2	90,50
15	*International Small Business Journal*	175	6	29,17
16	*Quarterly Journal of Economics*	166	2	83,00
17	*International Journal of Industrial Organization*	144	5	28,80
18	*Journal of Business Venturing*	138	3	46,00
19	*International Journal of Service Industry Management*	134	1	134,00
20	*Strategic Management Journal*	128	1	128,00
21	*Regional Studies*	126	7	18,00
22	*Industrial Marketing Management*	101	7	14,43
	Others	*2337*	*236*	*9,97*
	Total	**8981**	**412**	**62,58**

Table 1: Journal distribution ordered by total number of citations (with more than 100 citations)

With the total number of citations, this classification highlights the most influential journals in this field of study. Finally, according to Czapski (1997), another indicator could be the Average Citation per Paper (ACP). In our classification, we report this measure to show the magnitude of a certain journal. An example could be the journal *Organization Studies*, where only two papers have an ACP of 135,50, which the highest value in our dataset. Another relevant case can be the journal *Management Science,* where with only three papers it is placed in the third position of most cited journal within this field of study.

Furthermore, regarding the most relevant authors in this field, Table 2, summarizes the number of citations including the co-authored publications. Table 2 presents only authors with more than 100 citations according to Web of Science Core Collection database.

N.	Author's Name	Total Number of Citation (including co-authorship)
1	Damanpour, Fariborz	474
2	Von Hippel, Eric	432
3	Atuahene-Gima, Kwaku	326
4	Santamaria, Luis	253
5	Thomke, Stefan	251
6	Lukas, Brayan A.	208
7	Ferrell, Orville C.	208
8	Cooper, Robert G.	208
9	Ettile, John	208
10	Nieto, Maria Jesus	197

11	Koufteros, Xenophon	187
12	Vonderembse, Mark A.	187
13	Jayaram, Jay	187
14	Herstatt, Cornelius	181
15	Mowery, David C.	158
16	Reza, Ernesto M.	157
17	Mathieu, Valérie	152
18	Rogers, M	134
19	Banbury, Catherine M.	130
20	Mitchell, Will	130
21	Capon, Noel	128
22	Farley, Jouhn U.	128
23	Lehmann, Donald R.	128
24	Hulbert, James M.	128
25	Hatch, Nile W.	127
27	Roper, Stephen	101
28	Du, Jun	101
29	Love, Jim H.	101

Table 2: The most cited authors with more than 100 citations

Finally, the last part of this paragraph is focused on analyzing the most influential papers within this field of study. Table 3 summarizes the articles with more than 100 citations. In particular, we have seventeen papers with an ACP of 167.94. There were eleven (64.70%) empirical papers, two (11.76%) theory development, two (11.76%) meta-analysis, one (5.88%) case study, and one (5.88%) literature review.

Times Cited	Author(s)	Title	Type	Journal	Year	Key Results
253	Thomke S., Von Hippel E.	Customers as innovators – a new way to create value	Theory Development	*Harvard Business Review*	2002	The paper highlights the importance of heeding customers' needs to build up the product innovation trajectories. It is possible by involving the customers in the development process and test process. This paper examines the outcome of this innovative approach noting reduction of cost, more created value, and more customer satisfaction.
246	Damanpour F.	Organizational complexity and innovation: developing and testing multiple contingency models	Meta-Analysis	*Management Science*	1996	The study creates a model built on thirty years of data to understand the dichotomy between complexity-innovation and organizational-size innovation.
222	Damanpour F.	Organizational size and innovation	Meta-Analysis	*Organization Studies*	1992	The paper shows the influence of the organization type within firms, and the connection between firms with a small innovation division, and the advantages coming from a large innovation division.
214	Atuahene-Gima K.	Market orientation and innovation	Empirical	*Journal of Business Research*	1996	The study highlights the influence of market orientation and selected innovation characteristics in a firm on the success of service and product innovations.
198	Lukas B.A., Ferrell O.C.	The effect of market orientation on product innovation	Empirical	*Journal of the Academy of Marketing Science*	2000	The study stresses the relation between market orientation and product innovation. The main finding looks at customer orientation, which increases the introduction of new-to- the-world products and reduces the launching of me-too products. Additionally, competitor orientation increases the introduction of me-too products, and reduces the launching of line extensions and new-to-the-world products
196	Nieto M.J., Santamaria L.	The importance of diverse collaborative networks for the novelty of product innovation	Empirical	*Technovation*	2007	The study deepens the importance of collaboration by showing that experience in the management of alliances is reflected in better results regarding product innovation, and the choice of partners in the collaborative network may be a decisive decision for the success of innovation.
187	Koufteros X., Vonderembs M., Jayaram J.	Internal and external integration for product development: the contingency effect of uncertainty, equivocality, and platform strategy	Empirical	*Decision Sciences*	2005	The authors look at if the relationship between a high level of internal integration could lead to a higher level of external integration, looked at if contextual variables could moderate the linkages between integration strategy and performance. They demonstrated that both internal and external integration positively influences product innovation and profitability. The results also indicated that equivocality moderates the relationships between integration and performance.

177	Herstatt C., Von Hippel E.	From experience – developing new product concepts via the Lead User method - a case-study in a low-tech field	Case Study	*Journal of Product Innovation Management*	1992	The study demonstrates that the Lead User method has several advantages for product innovation regarding resources, time, and money expenditure with a better end-user satisfaction.
171	Cooper R.G.	Perspective: the Stage-Gate® idea-to-launch process-update, what's new, and NexGen systems	Literature Analysis	*Journal of Product Innovation Management*	2008	The paper offers a deep analysis of the benefits of the Stage-Gate® system by showing new challenges for firms and scholars, and a new possible direction for future research.
154	Ettlie J.E., Reza E.M.	Organizational integration and process innovation	Empirical	*Academy of Management Journal*	1992	The paper demonstrates how process innovation creates competitive advantage and productivity in manufacturing firms through new hierarchical structures, better coordination between design and manufacturing, and greater supplier cooperation.
138	Mathieu V.	Service strategies within the manufacturing sector: benefits, costs and partnership	Theory Development	*International Journal of Service Industry Management*	2001	The paper analyzes costs and benefits related to the service maneuver in manufacturing firms. It divides the maneuver into two types: service specificity and organizational intensity, deepens the relation between these two variables with the possibility to run a collaborative option. The author concludes that the most ambitious strategies provide more benefits to firms, but are also the riskiest due to associated multiple costs.
132	Rogers M.	Networks, firm size and innovation	Empirical	*Small Business Economics*	2004	The paper makes a comparison between manufacturing and non-manufacturing firms regarding innovation and networking. In particular, regarding innovation small manufacturing firms seem to have more advantages from networking as compared to mid-sized and large firms.
129	Banbury M., Mitchell W.	The effect of introducing important incremental innovations on market share and business survival	Empirical	*Strategic Management Journal*	1995	The study shows that incremental product development and rapid product introduction are strongly connected to business performance. The paper endorses the thesis that a business's survival is most influenced by its ability to support innovative products in the market and not only by its introduction of technically innovative products.
127	Capon N., Farley J.U., Lehmann D.R., Hulbert J.M.	Profiles of product innovators among large United-States manufacturers	Empirical	*Management Science*	1992	The paper explores how elements of environment, strategy, formal organization, and informal organization relate to product innovation and financial performance. It shows that a climate that encourages innovation and cooperation has a positive impact on impact financial returns.
109	Hatch N.W., Mowery D.C.	Process innovation and learning by doing in	Empirical	*Management Science*	1998	This study analyzes the relationship between process innovation and learning by doing. The paper demonstrates that acquired knowledge together with dedicated process development facilities, the

		semiconductor manufacturing				geographic proximity between development, and manufacturing facilities are significant in improving performance in introducing innovative technologies.
101	Roper S., Du J., Love J.H.	Modelling the innovation value chain	Empirical	*Research Policy*	2008	Considering that innovation events represent the end of a process of knowledge sourcing and transformation, the paper analyzes a large group of Irish firms and finds substantial complementarity between horizontal, forwards, backward, public, and internal knowledge sourcing activities. The resulted model emphasizes the role of skills, capital investment, and firms' other resources in the value creation process.
101	Atuahene-Gima K.	Differential potency of factors affecting innovation performance in manufacturing and services firms in Australia	Empirical	*Journal of Product Innovation Management*	1996	Building on a basis of Australian firms, this paper explores the managers' perceptions of the factors involved in successful NPD and NSD. The author finds that manufacturing firms focus their attention on product innovation advantage and quality whereas service firms focus more on human resources strategies.

Table 3: Most cited papers with more than 100 citations

4. HOMALS Positioning

After the brief presentation of journals, authors and papers in this field of research, in this research two types of HOMALS proximity analysis were made. The first isolated top journals, and made a comparison between journal keyword proximity by highlighting the journals that had similar keywords. The second proximity analysis compared the most repeated keywords by highlighting the stream of study and the proximity to the various subjects. The keywords selected were the keywords given by authors. Our choice is justified by the fact that instead of automatically tagging by WOS, authors could better describe the purpose, key results, and topic highlighting the paper's core (Zhang et al., 2015).

Moreover, HOMALS is a tool that allows researchers to see the distribution of topics and gives an idea of what it has happened in a certain field of study. The primary goal is not to only offer a statistical representation of repeated keyword, but to also by using a "big map" to show the proximity of topic to recognize how the scholars worked out each argument.

In fact, the middle of the map represents the average position of all the articles and therefore represents the center of studies in product and process innovation. For example, the keyword "performance" in Figure 3 is close to X=0; Y=0 as a large number of articles in product and process innovation focus on performance-related issues.

In both graphs, the axes are labeled by the authors through a ground process (Furrer et al., 2008; Gonzlalez-Louriero et al., 2015) that comes from a manual analysis and interpretation of the papers underlying the keywords.

Moreover, there is an important element regarding the dimension of the bubbles in the charts, that represents the weight of journals and keywords. This choice is justified because only using the simple positioning is not enough to catch the real importance given by data. It is important to note that the colors of the bubbles are not randomly selected but they represent the importance of various keywords/journals.

Finally, the Cronbach's Alpha which refers to the level of explanation regarding topic (keywords) variation is 0,966 and Eigenvalue is 21,567. Thus, we can therefore say, that Cronbach's Alphas shown a high level of reliability to the representation.

3.1 HOMALS Journal Positioning

The journal proximity map (Figure 2) is built by grouping the most repeated keywords in the database of the journals with the most citations, as identified in Table 1 (Duy and Vaughan, 2006; Garfield, 2006). After this process of isolation, we make a comparison between the keywords repeated more often in those groups.

In this case, the dimension of the bubbles represents the total number of citations in each journal according to Table 2. This second dimension, together with the positioning of the journals, allow on one side to identify the proximity of journals by topic, but also to identify which journals carried more weight in that field of study. In fact, the final result of HOMALS, as shown in Figure 2, displays how the journals selected were similar in topics and stream of research.

In addition, the colors represent the journals by importance according to the following scheme:

1. *Red*: between 1000 and 500 citations.
2. *Blue*: between 499 and 300 citations.
3. *Green*: between 299 and 200 citations.
4. *Gray*: between 199 and 100 citations.

By dividing the map into four quadrants it is possible to see that the significant aggregations are all around the right side of the map. Surprisingly, only the red and blue bubbles are clustered together in the first quadrant. However, the only exception is "Research Policy", which does not significantly cluster with any other journal.

Taking a wide interpretation of the map, it is also possible to recognize some area of interest by using the X and Y axis. It enables us to divide the journal position into two sides, on the right side (X>0) we have journals that are more focused on management and innovation management with product and process innovation as the core topic. On the opposite or left side, (X<0) we have more generalist journals that handle product and process innovation as a subsidiary topic. One example is the journal *Regional Study*, which in this analysis shows that it deals with this argument under the lens of collaborative network and alliances.

However, it is also possible to divide journals that discuss the referring topic in a more technical way by focusing on the technology exploitation by the firms (Y>0). On the opposite side, (Y<0) it is possible to find journals that debate about product and process innovation by analyzing the side effects of it, and by exploring this topic under the effect generated in the aggregate environment of firms like district and collaborative networks.

However, if we go into a detailed standpoint, it is possible to see a clustering of journals in the first quadrant where journals with more related topics are nearer to each other. In particular, within the first quadrant, HOMALS shows three significant aggregations.

The first cluster includes the *International Journal of Product Innovation Management, International Journal of Operations & Production Management, Small Business Economics*, and *Harvard Business Review*. This cluster focuses its attention on topics directly involved in the technical aspects of product innovation. In fact, within this area, we found keywords related in a technical and technological approach as the central theme instead of other clusters that analyze it under a more managerial perspective. Considering the number of citations within this group is possible to deliberate that this group is the most influential aggregation in the map.

The second cluster with *Technovation, Academy of Management Journal*, and *Decision Sciences*, focus its attention on innovation topics in a more managerial way instead of the previous cluster or “cluster one”. This clustering takes in consideration topics related to the management aspects of innovation with *Technovation* as the most representative journal in that group. This cluster represents the second relevant aggregation in this mapping, and HOMALS shows that this cluster is positioned near to the third one.

The third cluster is created from the journals *Management Science* and *Academy of Marketing Science*, and takes a “science approach” to the phenomenon. It also represents a relevant area of interest in this field, which is possible to see from the mapping. By referring to the first quadrant it is possible to identify in the three main clusters a significant positioning of *Journal of Business Research*, but this journal seems more isolated from the other three clusters in the positioning. This could be explained by the generalist approach to the phenomenon in question used by the journal.

Nevertheless, there are also other top journals with a strong weight that are not clustered together, as is the case with *Research Policy, Journal of Operations Management,* and *Industrial and Corporate Change*. This result highlights a fragmentation regarding the topic connected to “Product and Process Innovation in Manufacturing Firms”. In particular, *Research Policy* has a significant weight in this field, but is entirely isolated from the journals in the first quadrant. These results imply a relevant and important question, which is, how is the phenomenon of product and process innovation debated among the journals?

Thus, *Research Policy* represents one of the most influential journals in this field of study, yet it appears isolated from the other journals. It could be explained by the tendency of *Research Policy* to analyze the innovation process and innovation theories under a broader perspective, namely a policy perspective.

In conclusion, the evidence coming from the HOMALS analysis allows the researchers to recognize a balance between management and engineering oriented journals, and to note that the most influent journals that were taken into consideration have similar arguments and related research topics with the exception of *Research Policy*.

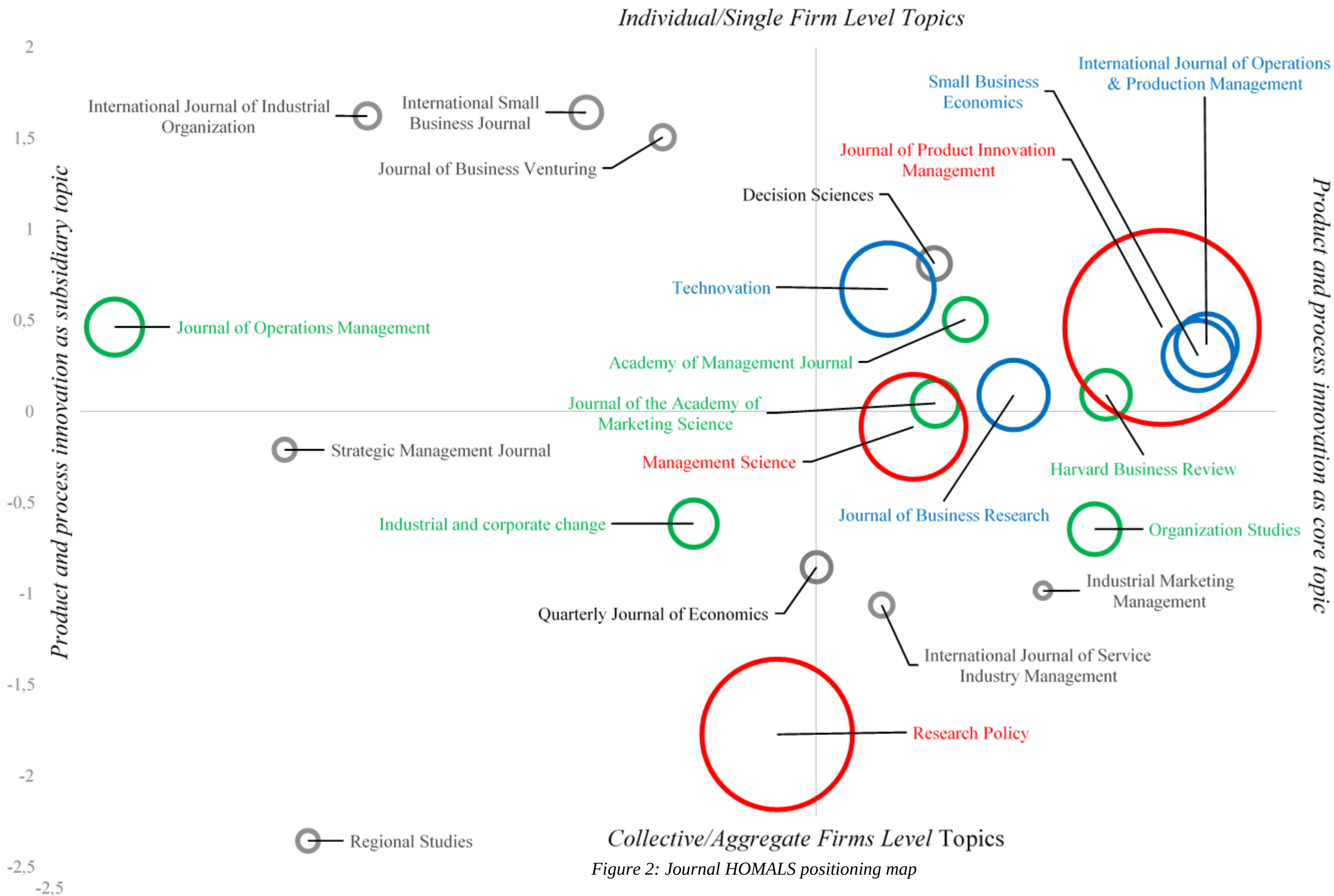

Figure 2: Journal HOMALS positioning map

4.2 HOMALS Keywords Positioning

Before introducing the keyword proximity analysis, it is necessary to note that this graph does not reflect the journal proximity. For example, if a journal is in the first quadrant it does not necessarily have the same keywords shown in the first quadrant of keyword's proximity map.
According to the literature (Su and Lee, 2010; Yoon et al., 2010; Chang et al., 2015; Khan and Wood, 2015), the keywords included in our analysis are summarized in Table 4. In the journal positioning map we include the most repeated words given by authors with a total number of fifteen or more appearances. N.P. means number of appearances.

Keyword	N.P.	Keyword	N.P.
Performance	178	Export	34
Patent	162	Firm size	34
Small firm	116	Radical innovation	34
Product development	111	Capability	31
Organization	104	Network	28
R&D	91	Competitive advantage	26
Knowledge	88	Open innovation	25
Management	87	Investments	25
Design	77	Innovation process	25
Supply chain	75	Adoption	24
Environment	69	Innovativeness	23
Innovation performance	55	Survival	23
Growth	50	Experience	23
Quality	46	Training	22
Marketing	45	Implementation	22
Production	40	Service firm	21
Spillover	39	Flexibility	18
Collaboration	38	Service innovation	17
Learning	37	Cooperation	17
Productivity	37	Innovation strategies	16
Competition	34	**TOTAL**	**2069**

Table 4: Most appeared keywords included in Figure 3 (with more than 15 appearances)

The following map (Figure 3) represents the distribution of keywords and their natural positioning. The color represents the keywords by the number of appearances, highlighting their importance:

1. *Red*: between 200 and 100 appearances.
2. *Blue*: between 99 and 50 appearances.
3. *Green*: between 49 and 30 appearances.
4. *Gray*: between 29 and 16 appearances.

As we did in the previous figure, the useful way to comprehend the distribution is to label the axis. It is possible to label the X axis as Degree of Single Firm or Aggregate Topic.
In that case with X<0, the map shows a topic connected to "single firm level" like "product development" or "design". On the opposite side, when we move to X>0 the topics are focused on a more aggregate level like "collaboration", "cooperation", "exports" and studies on "small firms" etc. where topics like "productivity" and "growth" are analyzed from an aggregate perspective.
We can also label the Y axis as Degree of Technical and Managerial Orientation. Where the keywords move through the ax Y>0, we get keywords that are connected more to a managerial approach to innovation. When the keywords move to Y<0, we get the opposite, that is keywords and topics that are clustering around a more technical oriented approach to product and process innovation.

Analyzing the graph, the representation clearly shows how the topics discussed under the big umbrella of product and process innovation in manufacturing firms are extensive. In fact, as the HOMALS shows, this type of innovation covers various aspects of traditional innovation studies.
The immediately noticeable evidence regards the word “performance, which together with “patent” has a primary role in this field of study. However, there is not a strong connection between these two topics, in fact, “performance” is more connect to “organization”, “environment” and “competitive advantage”. It also has a different positioning in terms of topics, and it is positioned on the left side, crossing the X axis. HOMALS shows that it is more focused on Individual Firm and Management than “patent”.
On the other side, data show that “patent” is positioned on the opposite axis, in fact, it appears in the third quadrant, and it relates to “R&D”, “competition” and “investments”.
The map shows other two relevant topics: “product development” and “small firm”. Regarding the first, it is at the end of X<0, and it is clustered with “design”, “management”, “supply chain”, and “marketing”. This demonstrates that these topics are tightly connected with product development, and scholars tend to examine these related arguments when they talk about product development. Otherwise, the relationship is still valid in the opposite way, for example, a scholar who wants to analyze management in this field will have a high probability to speak about product development instead “export” or “spillover” that are on the opposite side of the axis.
Finally, regarding “small firm”, this topic appears as the farthest from the center, and it also appears isolated from the others central topics. The only keyword closely connected is “survival”, and other relevant near-by topics are “export”, “experience”, and “service firm”.

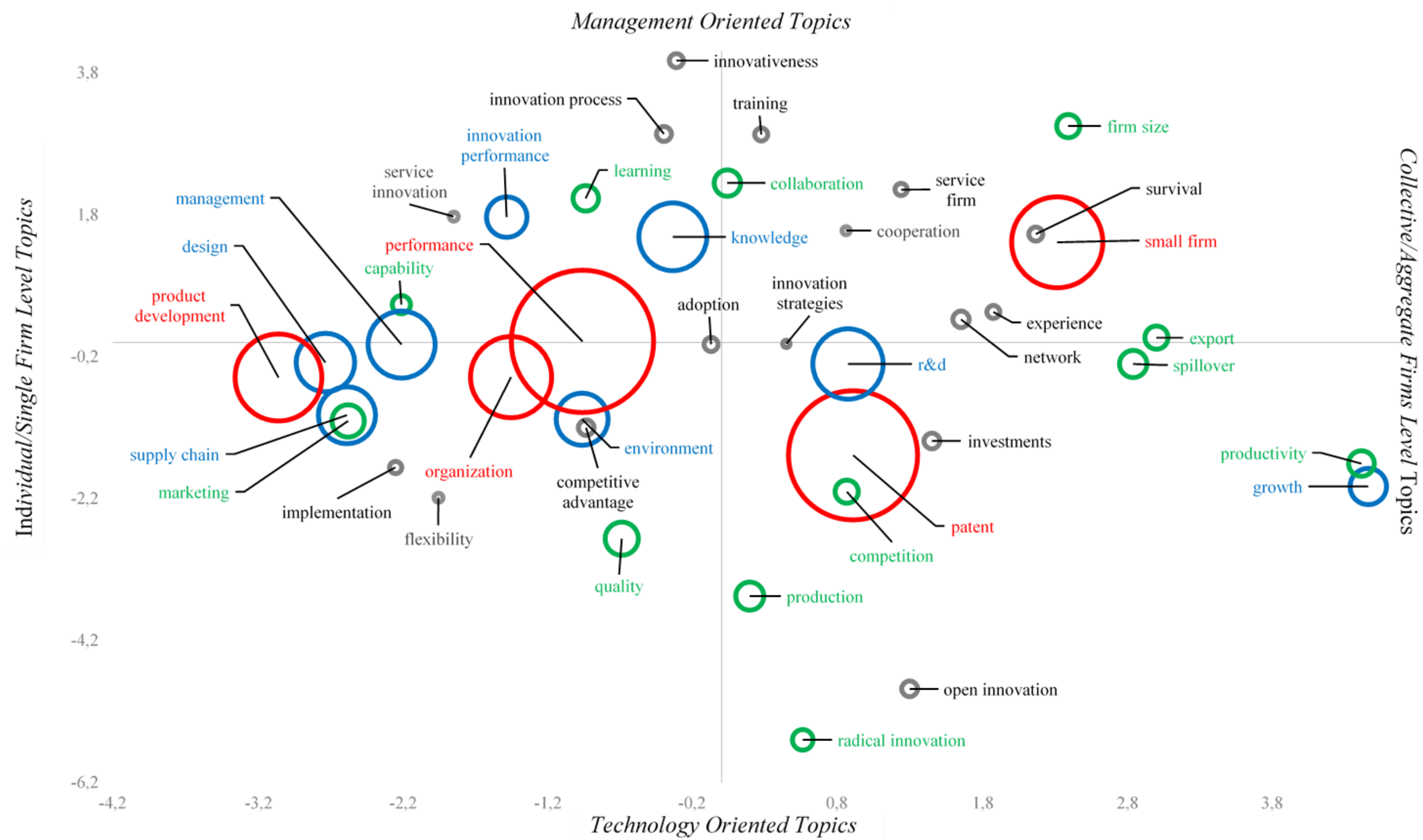

Figure 3: Authors' keywords HOMALS positioning map

5. Social Network Analysis

Regarding the relationship among journals and keywords, this is a two-mode network (affiliation network). In this context, SNA could be used as a support tool The network can be represented as a bipartite graph (Borgatti et al., 2002). Considering journals as nodes and keywords as events, journals that are related to each other are linked by the common keywords. The network represented in the following graph (Figure 4) has ninety-eight nodes in total (journals and keywords), where the blue square nodes represent the keywords and the red circle nodes represent the journals.

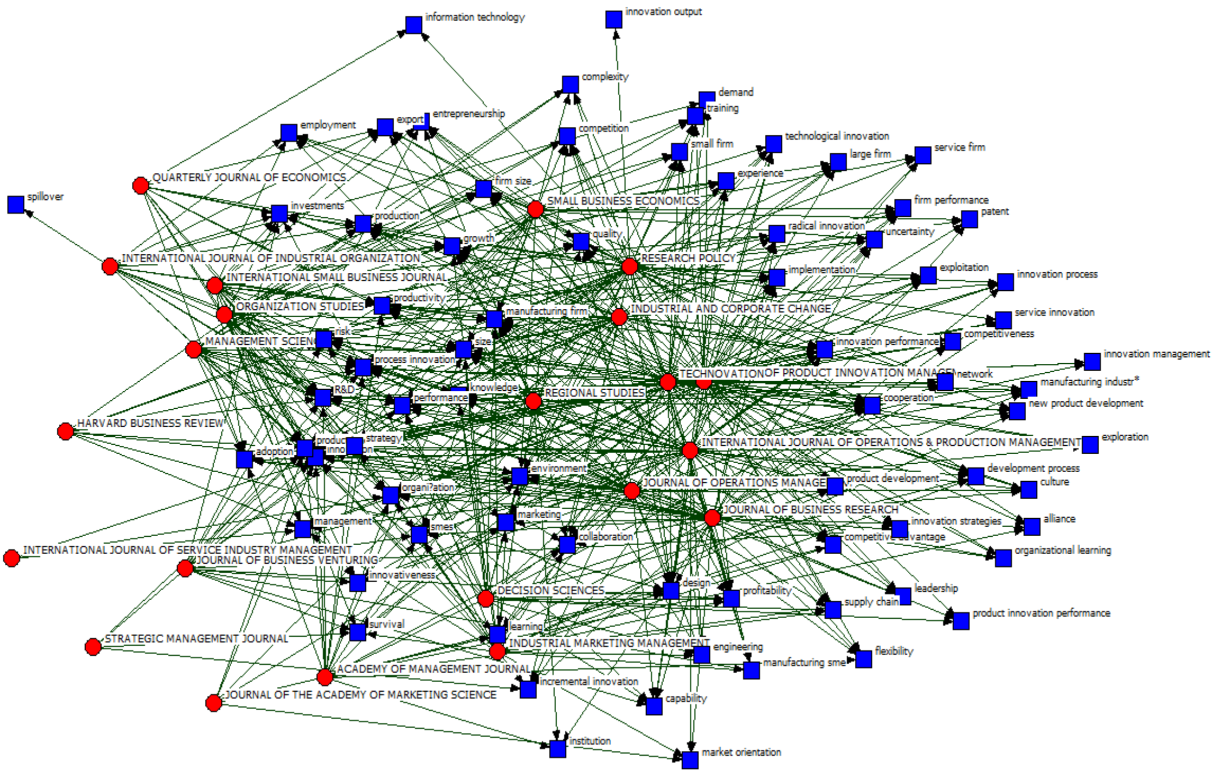

Figure 4: Journals and keywords network

Degree centrality and betweenness are two important measures that help to identify the most important actors in a network. In the graphs (Figure 5 and 6) below, the most important journals and the connections with keywords are identified according to degree centrality and betweenness (in absolute values), and are represented by the size of the nodes.

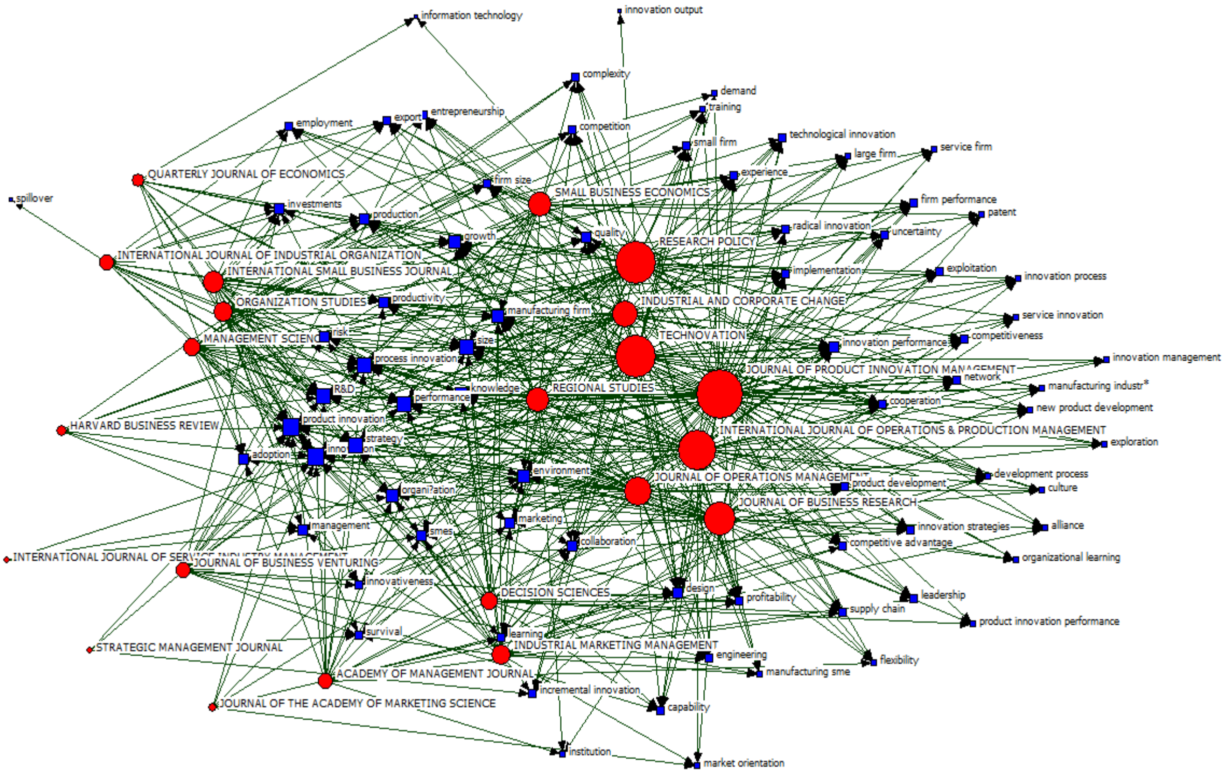

Figure 5: Network with the size of nodes according to Degree Centrality

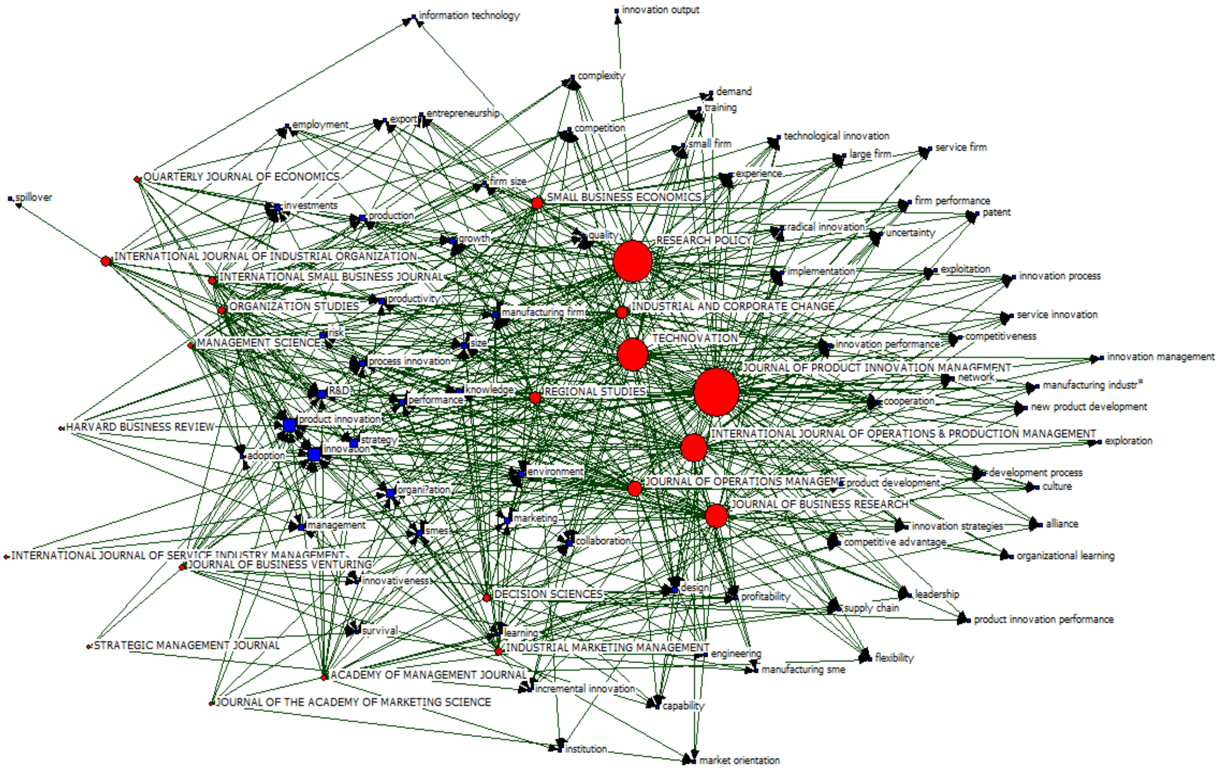

Figure 6: Network with the size of nodes according to Betweenness

As it is shown in the graphs above, the journals that have the highest degree (with a high number of connections to other journals) are the *Journal of Product Innovation Management*, *Research Policy*, *Journal of Business Research*, *Technovation*, and *International Journal of Operations & Production Management*. At the same time, the most important journals that connect sub-networks (betweenness) are *Journal of Product Innovation Management, Research Policy, Technovation, and International Journal of Operations & Production Management.*
With the ninety-eight nodes and the complex relationship among the journals and keyword, a centrality analysis of two-mode networks was calculated using UCINET 6.0 software (Borgatti et al., 2002). The centrality measures are normalized values, which points to journals that have high levels of centrality. This analysis shows all of the connections to the keywords, however, it emphasizes the keywords that are considered the most important because of their high levels of centrality. The following two tables (Table 5 and 6) show the numerical data from the aforementioned figures.

Journal	**Degree**	**Eigenvector**	**Closeness**	**Betweenness**
Journal of Product Innovation Management	0.829	0.391	0.819	0.173
Research Policy	0.724	0.353	0.738	0.145
Technovation	0.711	0.353	0.728	0.114
International Journal of Operations & Production Management	0.658	0.334	0.694	0.096
Journal of Business Research	0.526	0.257	0.621	0.074
Journal of Operations Management	0.461	0.249	0.590	0.042
Industrial and Corporate Change	0.434	0.242	0.578	0.036
Regional Studies	0.382	0.207	0.557	0.033
Small Business Economics	0.395	0.211	0.562	0.031
International Journal of Industrial Organization	0.211	0.123	0.492	0.027
International Small Business Journal	0.329	0.195	0.536	0.019
Industrial Marketing Management	0.303	0.166	0.527	0.019
Organization Studies	0.289	0.160	0.522	0.016
Decision Sciences	0.263	0.149	0.513	0.013
Management Science	0.276	0.167	0.518	0.012
Academy of Management Journal	0.237	0.135	0.504	0.012
Journal of Business Venturing	0.224	0.130	0.500	0.009
Quarterly Journal of Economics	0.158	0.097	0.480	0.006
Harvard Business Review	0.118	0.081	0.468	0.002
Journal of The Academy of Marketing Science	0.079	0.044	0.454	0.001
Strategic Management Journal	0.053	0.033	0.447	0.000
International Journal of Service Industry Management	0.039	0.027	0.434	0.000

Table 5: 2-Mode centrality measures for journals

Keywords	**Degree**	**Eigenvector**	**Closeness**	**Betweenness**
Innovation	0.955	0.222	0.989	0.035
Product innovation	0.955	0.222	0.989	0.035
Strategy	0.727	0.192	0.925	0.019
R&D	0.773	0.201	0.945	0.017

Organization	0.636	0.176	0.905	0.015
Performance	0.727	0.201	0.935	0.013
Process innovation	0.682	0.187	0.925	0.013
Size	0.682	0.191	0.915	0.011
Manufacturing firm	0.636	0.185	0.915	0.010
Knowledge	0.591	0.171	0.905	0.009
Management	0.455	0.126	0.860	0.009
Growth	0.545	0.159	0.896	0.008
Production	0.455	0.128	0.878	0.007
Environment	0.545	0.162	0.887	0.006
Productivity	0.455	0.127	0.878	0.006
Design	0.455	0.139	0.869	0.005
Risk	0.455	0.137	0.860	0.005
Smes	0.455	0.128	0.869	0.005
Marketing	0.409	0.127	0.860	0.005
Collaboration	0.409	0.126	0.869	0.005
Investments	0.409	0.106	0.851	0.005
Quality	0.409	0.125	0.851	0.004
Adoption	0.409	0.119	0.860	0.004
Technological innovation	0.318	0.102	0.835	0.004
Survival	0.318	0.080	0.811	0.004
Innovation performance	0.409	0.135	0.860	0.003
Implementation	0.364	0.123	0.851	0.003
Product development	0.364	0.120	0.851	0.003
Profitability	0.364	0.108	0.843	0.003
Learning	0.318	0.091	0.827	0.003
Export	0.318	0.084	0.819	0.003
Incremental innovation	0.273	0.075	0.811	0.003
Competition	0.364	0.114	0.843	0.002
Firm size	0.364	0.106	0.851	0.002
Cooperation	0.318	0.110	0.843	0.002
Competitive advantage	0.318	0.106	0.843	0.002
Entrepreneurship	0.318	0.100	0.835	0.002
Capability	0.318	0.091	0.811	0.002
Engineering	0.318	0.089	0.811	0.002
Innovativeness	0.318	0.089	0.827	0.002
Employment	0.273	0.073	0.768	0.002
Competitiveness	0.273	0.105	0.835	0.001
Exploitation	0.273	0.105	0.827	0.001
Firm performance	0.273	0.103	0.827	0.001
Experience	0.273	0.098	0.827	0.001
Leadership	0.273	0.095	0.811	0.001
Small firm	0.273	0.093	0.827	0.001
Network	0.273	0.091	0.819	0.001
Complexity	0.273	0.089	0.819	0.001

Supply chain	0.273	0.088	0.811	0.001
Radical innovation	0.273	0.086	0.819	0.001
Innovation strategies	0.273	0.085	0.819	0.001
Uncertainty	0.273	0.076	0.819	0.001
Service innovation	0.227	0.092	0.827	0.001
Innovation process	0.227	0.087	0.827	0.001
New product development	0.227	0.087	0.819	0.001
Culture	0.227	0.086	0.804	0.001
Training	0.227	0.080	0.811	0.001
Manufacturing industr*	0.227	0.078	0.811	0.001
Large firm	0.227	0.077	0.819	0.001
Development process	0.227	0.076	0.819	0.001
Flexibility	0.227	0.074	0.796	0.001
Manufacturing sme	0.227	0.069	0.827	0.001
Demand	0.182	0.067	0.811	0.001
Patent	0.182	0.066	0.811	0.001
Service firm	0.182	0.065	0.796	0.001
Alliance	0.182	0.062	0.811	0.001
Market orientation	0.182	0.044	0.729	0.001
Exploration	0.182	0.072	0.789	0.000
Organizational learning	0.182	0.068	0.796	0.000
Innovation management	0.136	0.059	0.775	0.000
Product innovation performance	0.136	0.043	0.782	0.000
Institution	0.136	0.033	0.683	0.000
Information technology	0.091	0.025	0.677	0.000
Innovation output	0.045	0.019	0.672	0.000
Spillover	0.045	0.007	0.512	0.000

Table 6: 2-Mode centrality measures for keywords

The journals are connected to the nodes of keywords, which are considered as main “bridges” among journals, and are analyzed by the betweenness. Therefore, the ten most important keywords (topics) are innovation, product innovation, strategy, R&D, organization, performance, process innovation, size, manufacturing firm, and knowledge.

By analyzing the centrality of journals, the relationship can be explained by the betweenness and degree of centrality. There is a clear relationship between degree and betweenness levels, which is an indicator that journals with more connections are important bridges connecting sub-networks at the same time. These journals, *Journal of Product Innovation Management, Research Policy, Technovation, International Journal of Operations & Production Management*, and *Journal of Business Research* connect to other journals’ sub-networks (sub-networks are considered as journal networks linked to other keywords or topics) by being connected to topics’ keywords (topics). Certain journals have "similar" importance, since they share the same keywords in common. These main keywords or topics can be considered common topics in the whole network. At the same time, journals that are close together are connected because they have similar profiles of events (keywords).

In comparing the SNA results with the HOMALS results, there exists a similarity among the order of the most important journals. However, the position of some journals differs significantly in the two lists. The journals that appear in different positions in the lists are *Small*

Business Economics, *Regional Studies*, *International Small Business Journal*, and *Management Science*. These common factors appear in these journals: The number of publications is low, and they have less than ten papers, however, the citation number is relatively high.
As it seen in the figure below (Figure 8), the explanation of the difference between the most important found keywords between HOMALS and SNA is explained by the number of connected nodes, as well as the importance of each connected node. For journals that appear important in the HOMALS results, show no importance in the SNA list. The nodes are keywords linked to a significant number of journals, which a few are important in the network. For keywords that are considered the most important in the SNA, they are keywords that are connected to significant journals that at the same time are considered important in the network. For keywords that are considered less important, these are the nodes that are connected to only to a few journals.

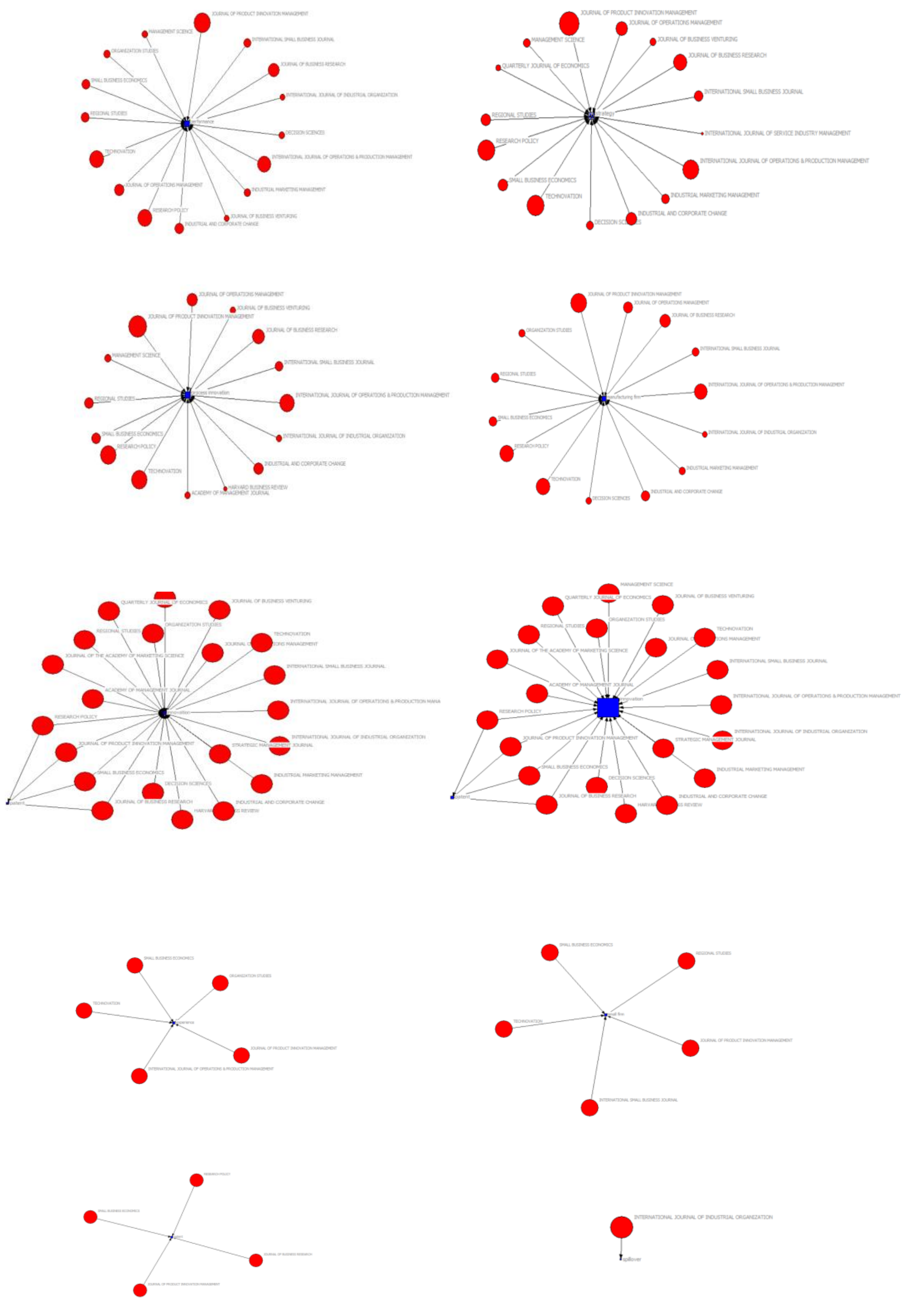

Figure 8: Networks identified through different approaches

6. Conclusion

Several scholars have reaffirmed the importance of product and process innovation for manufacturing firms (Smith and Tushman, 2005; Becheikh et al., 2006; Visnjic et al., 2016). However, this field of study is wide and involves numerous research streams. Especially in recent years, this field has met with growing attention by scholars (Malerba, 2002; Terziovski, 2010; Aas et al., 2015), and many changes in the manufacturing environment (Garcia and Calantone, 2002; Castellacci, 2008; Caputo et al., 2016; Holmström et al., 2016). Due to these changes, this field of study has become a tangled forest where it is difficult to identify hot topics and relevant journals.

The last available literature analysis specifically focused on product and process innovation in manufacturing firms goes back some more than ten years ago from Becheikh et al., (2006) where the authors highlighted the empirical results coming from the literature between 1993 and 2003. Despite this, a wide-ranging and recently updated perspective in this field of study was missing. Thus with this paper, we presented a comprehensive standpoint on product and process innovation in the manufacturing environment highlighting the main areas of interest, the most influent authors, and the most relevant journals.

In doing so we firstly used HOMALS, which has highlighted the topics' aggregation of several journals, distinguishing between those that prefers a technical approach to those that prefer a managerial approach. In that representation, however, it is clear that the most important journals clustered together except *Research Policy*. By HOMALS analysis, the most important journals are ranked according to the number of paper citations that can be compared to degree centrality in the SNA. This shows the advantage of the HOMALS method in providing the position of the journals and their importance according to citations; however, the information is more valuable when a SNA is associated with journals and the connection among the sub-networks and elements, which highlights the connection between journals and keywords.

Regarding the comparison between the two methods it is possible to state that HOMALS shows an overlapping of topics between the journals, whereas SNA highlights that the *Journal of Product Innovation Management* and *Research Policy* play a crucial role not only in the developing the knowledge base inside this field but also as "middlemen" that connect the other journals and topics.

The second mapping, which takes into consideration the keywords given by authors, shows five main topics (Performance, Patent, Small Firm, Product Development, Organization) which are connected to eight subtopics (R&D, Knowledge Management, Design, Supply Chain, Environment, Innovation Performance, Growth), and another twenty-eight residual topics. These topics and subtopics define the entire set of research streams in this field.

The results in both cases, HOMALS and SNA, present similarities beyond the differences in the position of journals and keywords. One of the main reasons for this difference is the objectives of these two methodologies. HOMALS provides the importance and location of journals and keywords, while SNA is focused on identifying the main actors and connection in the network.

Above and beyond this visual difference, both methods agree that the two journals *Journal of Product Innovation Management* and *Research Policy* are leading all the main research in this field of study and are providing a connection with all of the other topics. In addition, we canstate the same for the main identified keywords (Performance, Patent, Small Firm, Product Development, and Organization), which are representing the bridges and the poles of this field of study. The central aim of this work is to take stock of the current landscape, and to describe the evolution of a research field that in recent years has grown considerably by offering a comprehensive perspective to understand what happened in the past but also to offer several insights for future studies.

In particular, evidence is emerging with regard to future avenues of research that are connected to numerous trending topics that are changing product and process innovation in the manufacturing environment and that need to be extensively researched.

One promising future direction involves the areas of studies focused in startups and their real needs. Hyytinen et al., (2015) provocatively demonstrated that the connection between innovativeness and firms might have either a positive or a negative effect on firms' survival prospects, while the prior empirical works mostly suggests that the association is positive. The authors claim that future studies on the innovativeness–survival connection pay careful attention to two types of survivorship biases, namely bias of ideas and bias of survivorship with a particular focus on manufacturing startups.

As already mentioned in the literature review, very few studies have focused on process innovation., The study by Piening and Salge (2015)noted that the knowledge about how firms become process innovators is still underdeveloped. The authors offer a seminal contribution by connecting process innovation to dynamic capabilities. They highlight the antecedents, contingencies, and performance consequences of interfirm differences in process innovation successes in new production, supply chain, or administrative processes. They also call for more research that focuses on this unexplored field.

Nieto et al. (2015), focus their attention on innovation behavior in Spanish manufacturing firms by analyzing their innovation efforts, sources, and results. They demonstrate that family firms are less innovative, and are less disposed to turn to external sources of innovation than nonfamily firms. Family firms are more likely to achieve incremental innovations than radical innovations. However, a different geographical sample is needed and, moreover, several variables such as ownership, management, or governance need to be taken in consideration.

From a more engineering perspective, a breakthrough and relevant topic is the role of the Internet of Things and Industry 4.0 (Atzori et al., 2010; Caputo et al., 2015; Lee et al., 2015), which is the way to create what has been called a “smart factory”. More advancement is needed from a managerial perspective, in particular with regard to innovation management and how to efficiently exploit the transition from traditional to smart manufacturing.

Finally, although high technology firms hold a place of importance in any economy, innovative low-tech manufacturing firms still remain important contributors to the wealth of a country. In this vein, Maietta (2015), analyzed the impact between university collaboration in R&D and low-tech firms; the research highlights that product and process innovation are positively affected by geographical proximity to a university, but is negatively affected by the amount of its codified knowledge. However, due to the rapidly changing environment and the advent of new manufacturing philosophy (viz. Industry 4.0), it is crucial to understand how low-tech firms could deal with the new challenges in the manufacturing environment, and how universities could foster solutions to this new challenge.

Thus, the following figure (Figure 9) summarizes the most promising research avenues within innovation in the manufacturing environment.

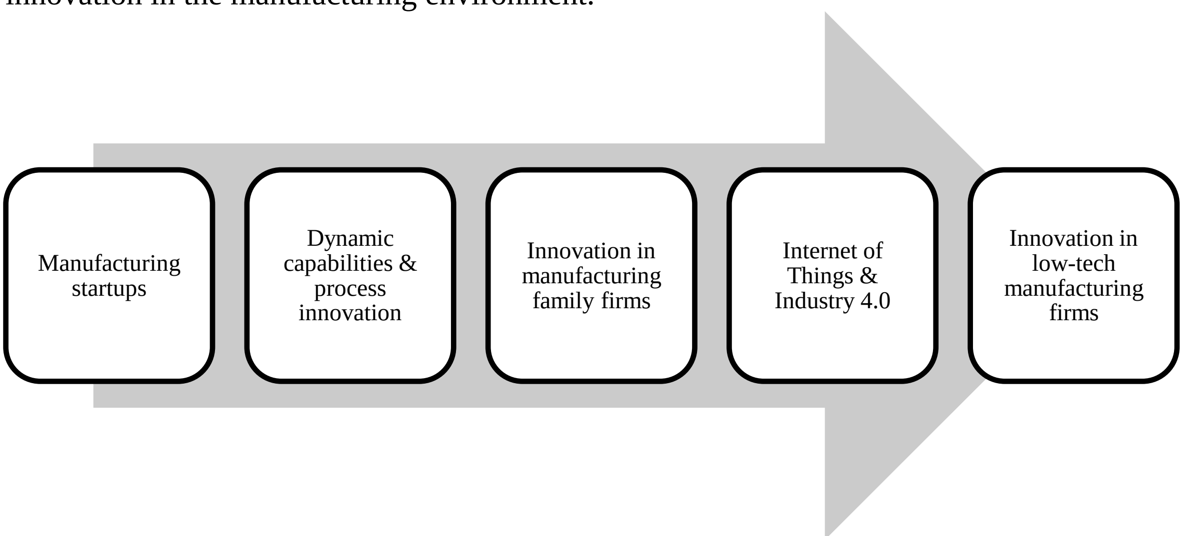

Figure 9 – Future avenues of research in the field of product and process innovation in manufacturing

In conclusion, we offer the research community insight into the outstanding and trending topics within this field of study by offering a guide through the rapidly changing environment of innovation in manufacturing.

Lastly, we have shown the importance of using the HOMALS analysis with SNA in order to discuss the emerging differences between those two methods. HOMALS offers an immediate snapshot, but SNA could help researchers understand the invisible connections between journals and topics.

Finally, regarding the limitation of the present study, we point out that above and beyond the rigorous method used, not all of the concepts presented in the articles themselves could be discussed. We conducted research within the WOS core collection. We also consulted Scopus with the aim to update recent research. However, the purpose of this study was to give a big picture of the field, and to offer a comprehensive approach to the field under study, as well as to give useful insight at a general level for the future development of trending streams. In addition, one limitation related to this work was the simplification needed to reach a visual model. The keyword mapping considers only the most relevant keywords with at least sixteen appearances and overlooks the other terms given by authors. This process offers a good data representation, but it reduces the depth of the analysis.

References

Aas, T. H., Breunig, K. J., Hydle, K. M., & Pedersen, P. E. (2015). Innovation Management Practices in Production-Intensive Service Firms. *International Journal of Innovation Management*, *19*(05), 1550055.

Adner, R., & Levinthal, D. (2001). Demand heterogeneity and technology evolution: implications for product and process innovation. *Management Science*, *47*(5): 611-628.

Al, U., Taşkın, Z., & Düzyol, G. (2002). Use of social network analysis in bibliometric researches. *e-Motion*, 40.

Alegre, J., & Chiva, R. (2008). Assessing the impact of organizational learning capability on product innovation performance: An empirical test. *Technovation*, *28*(6), 315-326.

Amara, N., & Landry, R. (2005). Sources of information as determinants of novelty of innovation in manufacturing firms: evidence from the 1999 statistics Canada innovation survey. *Technovation*, *25*(3), 245-259.

Amin, M., & Mabe, M. (2004). Impact factors: use and abuse. *International Journal of Environmental Science and Technology*, 1(1), 1.

Antonioli, D., Mancinelli, S., & Mazzanti, M. (2013). Is environmental innovation embedded within high-performance organisational changes? The role of human resource management and complementarity in green business strategies. *Research Policy*, *42*(4), 975-988.

Appio, F. P., Martini, A., Massa, S., & Testa, S. (2016). Unveiling the intellectual origins of Social Media-based innovation: insights from a bibliometric approach. *Scientometrics*, *108*(1), 355-388.

Arrow, K. (1962). Economic welfare and the allocation of resources for invention. In *The rate and direction of inventive activity: Economic and social factors* (pp. 609-626). Princeton University Press.

Asheim, B. T., & Isaksen, A. (1997). Location, agglomeration and innovation: towards regional innovation systems in Norway?. *European planning studies*, *5*(3), 299-330.

Atzori, L., Iera, A., & Morabito, G. (2010). The internet of things: A survey. *Computer networks*, *54*(15), 2787-2805.

Becheikh N., Landry R., & Amara N. (2006). Lessons from innovation empirical studies in the manufacturing sector: A systematic review of the literature from 1993-2003, *Technovation*, *26*(5): 644-664.

Bendixen, M., & Sandler, M. (1995). Converting verbal scales to interval scales using correspondence analysis, *Management Dynamics: contemporary research*, *4*(1): 32-50.

Bi, Z. M., Lang, S. Y., Shen, W., & Wang, L. (2008). Reconfigurable manufacturing systems: the state of the art. *International Journal of Production Research*, *46*(4): 967-992.

Borgatti, S.P., Everett, M.G. and Freeman, L.C. (2002). *Ucinet for Windows: Software for Social Network Analysis*. Harvard, MA: Analytic Technologies.

Brown, S. L., & Eisenhardt, K. M. (1995). Product development: Past research, present findings, and future directions. *Academy of management review*, *20*(2), 343-378.

Buffington, J. (2016). The Future of Manufacturing: An End to Mass Production. In *Frictionless Markets* (pp. 49-65). Springer International Publishing.

Camisón-Zornoza, C., Lapiedra-Alcamí, R., Segarra-Ciprés, M., & Boronat-Navarro, M. (2004). A meta-analysis of innovation and organizational size. *Organization Studies*, *25*(3), 331-361.

Caputo A., Marzi G. & Pellegrini M.M. (2016). The Internet of Things in manufacturing innovation processes: development and application of a conceptual framework, *Business Process Management Journal*, *22*(2): 383-402

Castellacci, F. (2008). Technological paradigms, regimes and trajectories: Manufacturing and service industries in a new taxonomy of sectoral patterns of innovation. *Research Policy*, *37*(6), 978-994.

Chang, Y. W., Huang, M. H., & Lin, C. W. (2015). Evolution of research subjects in library and information science based on keyword, bibliographical coupling, and co-citation analyses. *Scientometrics*, *105*(3), 2071-2087.

Clark, K. B., & Fujimoto, T. (1991). *Product development and performance*. Boston: Harvard Business School Press.

Coe, D. T., & Helpman, E. (1995). International r&d spillovers. *European Economic Review*, *39*(5), 859-887.

Crossan, M. M., & Apaydin, M. (2010). A multi-dimensional framework of organizational innovation: A systematic review of the literature. *Journal of Management Studies*, *47*(6), 1154-1191.

Czapski, G. (1997). The use of deciles of the citation impact to evaluate different fields of research in Israel. *Scientometrics*, *40*(3): 437-443.

Dabic, M., González-Loureiro, M., & Furrer, O. (2014). Research on the strategy of multinational enterprises: key approaches and new avenues, *Business Research Quarterly*, *17*(2): 129-148.

Gonzalez-Loureiro, M., Dabić, M., & Kiessling, T. (2015). Supply chain management as the key to a firm's strategy in the global marketplace: Trends and research agenda. *International Journal of Physical Distribution & Logistics Management*, 45(1/2), 159-181.

Dabic, M., González-Loureiro, M., & Harvey, M. (2015). Evolving research on expatriates: what is ‘known’after four decades (1970–2012). *The International Journal of Human Resource Management*, *26*(3), 316-337.

Daft, R. L. (1978). A dual-core model of organizational innovation, *Academy of Management Journal*, 21(2): 193-210.

Damanpour F. (1991). Organizational Innovation: A Meta-Analysis of Effects of Determinants and Moderators, *The Academy of Management Journal*, 34(3): 555-590.

Davies, A. (2004). Moving base into high-value integrated solutions: a value stream approach. *Industrial and Corporate Change*, *13*(5), 727-756.

De Leeuw, J., & Mair, P. (2009). Gifi Methods for Optimal Scaling in R: The Package HOMALS. *Journal of Statistical Software*, 31(i04).

De Massis, A., Frattini, F., Pizzurno, E., & Cassia, L. (2015). Product innovation in family versus nonfamily firms: An exploratory analysis. *Journal of Small Business Management*, *53*(1), 1-36.

Dewar R.D., Dutton J.E. (1986). The adoption of radical and incremental innovations: An empirical analysis, *Management Science*, 32(11): 1422-1433.

Drucker, P. (1994). *Innovation and entrepreneurship* (2nd ed.). Oxford: Butterworth-Heinemann

Duy, J., & Vaughan, L. (2006). Can electronic journal usage data replace citation data as a measure of journal use? An empirical examination. *The Journal of Academic Librarianship*, *32*(5), 512-517.

Engelbrecht, H. J. (1997). International R&D spillovers, human capital and productivity in OECD economies: An empirical investigation. *European Economic Review*, *41*(8), 1479-1488.

Ettlie J.E., Bridges W.P., O'Keefe R.D. (1984). Organization strategy and structural differences for radical versus incremental innovation *Management Science*, 30(6): 682-695.

Fagerberg, J., Fosaas, M., & Sapprasert, K. (2012). Innovation: Exploring the knowledge base. *Research Policy*, 41:1132-1153.

Falagas, M. E., Pitsouni, E. I., Malietzis, G. A., & Pappas, G. (2008). Comparison of PubMed, Scopus, web of science, and Google scholar: strengths and weaknesses. *The FASEB Journal*, *22*(2): 338-342.

Furrer, O., Thomas, H., & Goussevskaia, A. (2008). The structure and evolution of the strategic management field: A content analysis of 26 years of strategic management research, *International Journal of Management Reviews*,*10*(1): 1-23.

Garcia, R., & Calantone, R. (2002). A critical look at technological innovation typology and innovativeness terminology: a literature review. *Journal of Product Innovation Management*, *19*(2), 110-132.

Garfield, E. (2006). The history and meaning of the journal impact factor. *Jama*,*295*(1), 90-93.

Garfield, E., & Pudovkin, A. (2015). Journal Impact Factor Strongly Correlates with the Citedness of the Median Journal Paper. *Collnet Journal of Scientometrics and Information Management*, *9*(1), 5-14.

Gifi, A. (1990). Nonlinear multivariate analysis, *John Wiley and Sons. Chichester, England*.

González-Loureiro, M., Dabic, M., Furrer, O. (2015). A content and comparative analysis of strategic management research in the Baltic area, *Baltic Journal of Management*,10(2): 243 - 266.

Guellec, D., & de la Potterie, B. V. P. (2001). The internationalisation of technology analysed with patent data. *Research Policy*, *30*(8), 1253-1266.

Hall, C. M., & Page, S. J. (2015). Following the impact factor: Utilitarianism or academic compliance?. *Tourism Management*, *51*, 309-312.

Hobday, M. (2005). Firm-level innovation models: perspectives on research in developed and developing countries. *Technology analysis & strategic management*, *17*(2), 121-146.

Hoffman, D. L., & De Leeuw, J. (1992). Interpreting multiple correspondence analysis as a multidimensional scaling method. *Marketing Letters*, *3*(3): 259-272.

Holmström, J., Holweg, M., Khajavi, S. H., & Partanen, J. (2016). The direct digital manufacturing (r) evolution: definition of a research agenda, *Operations Management Research*, 1-10.

Hsieh, P. N., & Chang, P. L. (2009). An assessment of world-wide research productivity in production and operations management. *International Journal of Production Economics*, 120: 540-551.

Hyytinen, A., Pajarinen, M., & Rouvinen, P. (2015). Does innovativeness reduce startup survival rates?. *Journal of Business Venturing*, *30*(4), 564-581.

Ireland, R. D., & Webb, J. W. (2007). Strategic entrepreneurship: Creating competitive advantage through streams of innovation. *Business Horizons*, *50*(1), 49-59.

Kamien, M. I., & Schwartz, N. L. (1982). *Market structure and innovation*. Cambridge University Press.

Kanter, R. M. (2001). *Evolve! Succeeding in the digital culture of tomorrow*. Boston: Harvard Business School Press

Khan, G. F., & Wood, J. (2015). Information technology management domain: emerging themes and keyword analysis. *Scientometrics*, *105*(2), 959-972.

Kimberly J.R., Evanisko M.J. (1981). Organizational innovation: The influence of individual, organizational, and contextual factors on hospital adoption of technological and administrative innovations, *The Academy of Management Journal*, 24(3): 689-713.

Knight, G. A., & Cavusgil, S. T. (2004). Innovation, organizational capabilities, and the born-global firm. *Journal of International Business Studies*, 352: 124-141.

Landström, H., Harirchi, G., & Aström, F. (2012). Entrepreneurship: Exploring the knowledge base. *Research Policy*, 41: 1154-1181.

Länsisalmi, H., Kivimäki, M., Aalto, P., & Ruoranen, R. (2006). Innovation in healthcare: a systematic review of recent research. *Nursing Science Quarterly*, *19*(1), 66-72.

Lee, J., Bagheri, B., & Kao, H. A. (2015). A cyber-physical systems architecture for industry 4.0-based manufacturing systems. *Manufacturing Letters*, *3*, 18-23.

Leydesdorff, L., Carley, S., & Rafols, I. (2013). Global maps of science based on the new Web-of-Science categories. *Scientometrics*, *94*(2), 589-593.

Lin, R. J., Tan, K. H., & Geng, Y. (2013). Market demand, green product innovation, and firm performance: evidence from Vietnam motorcycle industry. *Journal of Cleaner Production*, *40*, 101-107.

Maietta, O. W. (2015). Determinants of university–firm R&D collaboration and its impact on innovation: A perspective from a low-tech industry. *Research Policy*, *44*(7), 1341-1359.

Malerba, F. (2002). Sectoral systems of innovation and production. *Research Policy*, *31*(2), 247-264.

Marzi, G., Caputo, A. & Dabic M. (2017a) Management Lessons from Italy: a bibliometric analysis of top Italian based scholars and studies published from 1985 to 2015. *International Journal of Critical Accounting*, Forthcoming

Marzi, G., Rialti, R., Marina, D., & Caputo, A. (2017b). A mixed methods bibliometric investigation of the World Review of Entrepreneurship, Management and Sustainable Development: from qualitative to quantitative data. *World Review of Entrepreneurship, Management and Sustainable Development*, Forthcoming

Nord w. R., Tucker, S. (1987). *Implementing routine and radical innovation*, Lexington Books: Lexington, MA.

OECD. (1997). The Measurement of Scientific and Technological Activities, Proposed Guidelines for Collecting and Interpreting Technological Innovation Data. *Paris: Organization for Economic Cooperation and Development.*

Otte, E., & Rousseau, R. (2002). Social network analysis: a powerful strategy, also for the information sciences. *Journal of Information Science*, *28*(6), 441-453.

Peres, R., Muller, E., & Mahajan, V. (2010). Innovation diffusion and new product growth models: A critical review and research directions. *International Journal of Research in Marketing*, *27*(2), 91-106.

Piening, E. P., & Salge, T. O. (2015). Understanding the antecedents, contingencies, and performance implications of process innovation: A dynamic capabilities perspective. *Journal of Product Innovation Management*, *32*(1), 80-97.

Pittaway, L., Robertson, M., Munir, K., Denyer, D., & Neely, A. (2004). Networking and innovation: a systematic review of the evidence. *International Journal of Management Reviews*, *5*(3-4), 137-168.

Podsakoff, P. M., MacKenzie, S. B., Podsakoff, N. P., & Bachrach, D. G. (2008). Scholarly influence in the field of management: A bibliometric analysis of the determinants of university and author impact in the management literature in the past quarter century. *Journal of Management*, (34): 641-720.

Prajogo, D. I. (2006). The relationship between innovation and business performance—a comparative study between manufacturing and service firms. *Knowledge and Process Management*, *13*(3): 218-225.

Reichstein, T., & Salter, A. (2006). Investigating the sources of process innovation among UK manufacturing firms. *Industrial and Corporate Change*, *15*(4), 653-682.

Roos, G. (2015). Servitization as Innovation in Manufacturing—A Review of the Literature, In *The Handbook of Service Innovation* (pp. 403-435). Springer: London.

Schroeder, R. G., Scudder, G. D., & Elm, D. R. (1989). Innovation in manufacturing. *Journal of Operations Management*, *8*(1): 1-15.

Schumpeter, J. (1942). Creative destruction. *Capitalism, Socialism and Democracy*, *825*.

Schumpeter, J.A., (1934). *Theory of economic development*, Harvard University Press, Cambridge, MA.

Scotchmer, S. (2004). *Innovation and incentives*. MIT Press. Cambridge MA

Shepherd, C., & Ahmed, P. K. (2000). From product innovation to solutions innovation: a new paradigm for competitive advantage. *European Journal of Innovation Management*, *3*(2), 100-106.

Smith W.K., Tushman M.L. (2005). Managing strategic contradictions: A top management model for man-aging innovation streams, *Organization Science*, 16(5): 522-536.

Smith, A. (1776). An Inquiry into the Nature and Causes of the Wealth of Nations

Su, H. N., & Lee, P. C. (2010). Mapping knowledge structure by keyword co-occurrence: a first look at journal papers in Technology Foresight. *Scientometrics*, *85*(1), 65-79.

Terziovski, M. (2010). Innovation practice and its performance implications in small and medium enterprises (SMEs) in the manufacturing sector: a resource-based view. *Strategic Management Journal*, *31*(8), 892-902.

Utterback J.M., Abernathy W.J. (1975). A dynamic model of process and product innovation, *Omega*, 3(6): 639-656.

Veugelers, R., & Cassiman, B. (1999). Make and buy in innovation strategies: evidence from Belgian manufacturing firms. *Research Policy*, *28*(1), 63-80.

Visnjic, I., Wiengarten, F., & Neely, A. (2016). Only the Brave: Product Innovation, Service Business Model Innovation, and Their Impact on Performance. *Journal of Product Innovation Management*, *33*(1): 36-52.

Wellman, B., & Berkowitz, S. D. (1988). *Social structures: A network approach* (Vol. 2). CUP Archive.

Wu, D., Rosen, D. W., Wang, L., & Schaefer, D. (2015). Cloud-based design and manufacturing: A new paradigm in digital manufacturing and design innovation. *Computer-Aided Design*, *59*, 1-14.

Yoon, B., Lee, S., & Lee, G. (2010). Development and application of a keyword-based knowledge map for effective R&D planning. *Scientometrics*, *85*(3), 803-820.

Zhang, J., Yu, Q., Zheng, F., Long, C., Lu, Z., & Duan, Z. (2015). Comparing keywords plus of WOS and author keywords: A case study of patient adherence research. *Journal of the Association for Information Science and Technology*, 67(4), 967–972.

Zhang, W., Zhang, Q., Yu, B., & Zhao, L. (2015). Knowledge map of creativity research based on keywords network and co-word analysis, 1992–2011.*Quality & Quantity*, *49*(3), 1023-1038.

Zhao, R., & Chen, B. (2014). Applying author co-citation analysis to user interaction analysis: a case study on instant messaging groups. *Scientometrics*,*101*(2), 985-997.

Zhu, L., Liu, X., He, S., Shi, J., & Pang, M. (2015). Keywords co-occurrence mapping knowledge domain research base on the theory of Big Data in oil and gas industry. *Scientometrics*, *105*(1), 249-260.